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Comparison of Quality and Rescuer Fatigue Between Mechanical and Manual Chest Compressions in a Simulated In-Hospital Cardiac Arrest Scenario: A High-Fidelity Simulation Randomized Crossover Controlled Study

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Abstract

Background

High-quality cardiopulmonary resuscitation (CPR) is fundamental to improving outcomes in cardiac arrest. This study aimed to comprehensively compare the quality of mechanical versus manual chest compressions in defibrillable and non-defibrillable rhythms within a simulated in-hospital cardiac arrest setting, and to quantify rescuer fatigue using high-fidelity simulation.

Method

A prospective, randomized, crossover, controlled study was conducted. Sixty healthcare providers holding valid advanced life support certification were organized into 20 three-member teams (each comprising one physician and two nurses). Each team performed four 15-minute simulated in-hospital cardiac arrest scenarios in random sequence: (1) manual compressions with non-defibrillable rhythm; (2) manual compressions with defibrillable rhythm (ventricular fibrillation/pulseless ventricular tachycardia); (3) mechanical compressions with non-defibrillable rhythm; and (4) mechanical compressions with defibrillable rhythm. A washout period of at least 3 days was maintained between scenarios. Scenarios were conducted using a high-fidelity patient simulator capable of real-time recording and feedback of CPR quality metrics. Primary outcomes included chest compression depth (CCD), chest compression rate (CCR), proportion of correct compression depth (PCCD), chest compression recoil rate (CCRR), proportion of correct compression rate (PCCR), chest compression fraction (CCF), rescuer fatigue score (RFP), and overall compression quality (CCQ). Data were analyzed using repeated-measures analysis of variance.

Results

(1) Regardless of whether defibrillation or not, with the increase of compression time, the quality of manual compression decreased, the compression frequency increased, and the fatigue value gradually increased. However, in the mechanical compression group, with the increase of compression time, the quality of compression did not change significantly;(2) The data dispersion of compression depth and compression frequency in the artificial cardiopulmonary resuscitation group was higher than that in the mechanical cardiopulmonary resuscitation group;(3) In the three stages of simulation, there were significant differences in the quality indicators of manual compression among the groups with the increase of compression time. The compression depth and chest rebound showed a downward trend, while the compression rate and the fatigue value of rescuers showed an upward trend;(4) In the three stages of simulation, except for the first stage, with the increase of compression time, the quality indicators and fatigue values of artificial cardiopulmonary resuscitation were significantly different from those of mechanical cardiopulmonary resuscitation.

Conclusion

In the simulation scenario of in-hospital CPR, mechanical CPR has better compression quality and stability than manual CPR, and can reduce the fatigue value of rescuers.

Introduction

Cardiac arrest (CA) remains a leading cause of global mortality. Survival rates for both in-hospital cardiac arrest (IHCA) and out-of-hospital cardiac arrest (OHCA) have remained persistently low at hospital discharge over prolonged periods [1, 2]. High-quality, uninterrupted chest compressions (CCs), as a core component of cardiopulmonary resuscitation (CPR), are directly linked to improved return of spontaneous circulation (ROSC) and favorable neurological outcome [3]. International resuscitation guidelines, including those from the American Heart Association (AHA) and the European Resuscitation Council (ERC), clearly define the criteria for high-quality CPR, specifying a compression depth of 5–6 cm, a rate of 100–120 compressions per minute, complete chest recoil, and minimization of pauses in chest compressions [4, 5].

Although the guidelines provide comprehensive recommendations and training for standardized manual chest compressions (MCC), maintaining consistent compression quality remains challenging in real-world clinical settings. Evidence indicates that even trained healthcare providers may exhibit a progressive decline in both compression depth and rate due to physical fatigue after several minutes of continuous chest compressions, thus failing to meet guideline-specified targets [6, 7]. Furthermore, during resuscitation, essential interventions—such as advanced airway placement, intravenous access, medication administration, rhythm analysis, and defibrillation—inevitably interrupt chest compressions. These interruptions compromise coronary and cerebral perfusion pressures and may negatively impact resuscitation outcomes[8, 9]. Notably, when defibrillation is required for shockable rhythms (e.g., ventricular fibrillation or pulseless ventricular tachycardia), the resuscitation team must pause compressions before and after the shock for safety reasons. This "no-flow" period is particularly detrimental to patient prognosis [10].

To overcome the inherent limitations of manual chest compressions, mechanical chest compression (Mech - CC) devices have been developed. These devices are designed to deliver continuous, stable, and high - quality chest compressions at pre-set depths and frequencies. In theory, they can eliminate the influence of rescuer fatigue and significantly reduce the compression interruption time[11, 12]. Existing research has explored the application value of mechanical compressions in various scenarios, and the majority of studies suggest their remarkable advantages in maintaining compression consistency[13, 14]. Nevertheless, direct, multi - dimensional quality comparison studies between mechanical compressions and team - based CPR in different clinical simulation scenarios (especially defibrillable and non - defibrillable rhythms), particularly in the context of in - hospital cardiopulmonary resuscitation (CPR), remain relatively scarce.

Furthermore, rescuer fatigue not only affects the quality of compressions but may also impair the cognitive function and decision - making ability of the entire resuscitation team. The use of mechanical devices can relieve rescuers from strenuous physical labor, enabling them to concentrate on other advanced life support tasks, such as etiology diagnosis, medication management, and team collaboration[15]. However, the effectiveness of this "relief" in reducing fatigue requires quantitative assessment using a combination of subjective and objective indicators.

Therefore, this study conducted a rigorous randomized crossover controlled simulation study to examine whether mechanical chest compressions (MCCs) exhibit significant differences compared to manual compressions performed by a three - member team of experienced healthcare professionals in a highly standardized simulated in - hospital cardiac arrest scenario. The differences were evaluated in the following aspects: (a) core compression quality parameters; (b) compression continuity; and (c) rescuer subjective fatigue. Additionally, the study explored whether these differences would vary depending on the resuscitation scenario (with or without defibrillation). This research aims to provide a more robust evidence - based medical foundation for optimizing in - hospital cardiopulmonary resuscitation (CPR) strategies and the clinical application of mechanical compression devices.

Methods

Trial Design

This study adopted a prospective, single - blind (analyst - blind), randomized, sequential crossover design. This design was implemented to guarantee that each participating team (serving as an analysis unit) underwent all four experimental conditions, thus eliminating inter - group variability and enabling each team to act as its own control. The four experimental conditions were defined as follows: (1) Artificial - Non - defibrillation group: The team conducted 15 minutes of artificial chest compressions on a model simulating non - defibrillating rhythm (absence of electrical activity or cardiac arrest).(2) Artificial - Defibrillation group: The team carried out 15 minutes of artificial chest compressions on a model simulating defibrillating rhythm (ventricular fibrillation/non - pulsatile ventricular tachycardia), during which two rhythm analyses and defibrillations were performed in accordance with a predefined protocol.(3) Mechanical - Non - defibrillation group: After the initial assessment, the team promptly deployed a mechanical compression device, which executed 15 minutes of chest compressions simulating the rhythm in group (1).

(4) Mechanical - Defibrillation group: The team deployed a mechanical compression device to perform 15 minutes of compressions simulating the rhythm in group (2). During the process, two rhythm analyses and defibrillations were carried out, and the device remained operational throughout the defibrillation.The order in which each team participated in the four scenarios was determined by a computer - generated random sequence. To preclude potential impacts of cumulative fatigue and skill acquisition on subsequent experiments, a washout period of at least 3 days (72 hours) was set between each pair of simulated scenarios for each team.

Participants

This study enlisted 60 healthcare professionals from the Emergency Department, Intensive Care Unit (ICU), and Cardiac Center. All participants were required to satisfy the following inclusion criteria: (1) Possession of a valid practicing physician or registered nurse qualification certificate; (2) Holding a valid Advanced Cardiac Life Support (ACS) certification within the past two years; (3) Participation in basic life support and mechanical cardiopulmonary resuscitation (CPR) equipment operation training and successful completion of the assessment every 3 months within the year preceding the study; (4) Participation in at least 5 real hospital cardiac arrest resuscitations within the year preceding the study; (5) Absence of musculoskeletal disorders that could impede the performance of high - quality chest compressions. Exclusion criteria were as follows: (1) Inability to complete all four simulated scenarios; (2) Occurrence of health problems that affected their work during the study period.

A total of 60 participants were grouped into 20 standard three - member resuscitation teams, with each team composed of one physician and two nurses, to mimic the typical composition of in - hospital resuscitation teams. Before the study, demographic and professional background data (including age, gender, height, weight, occupation, years of service, and the time of advanced cardiovascular life support certification) of all team members were documented.

This research protocol has obtained approval from the Institutional Review Board (IRB) (Ethical Approval Number: [2026-028-01]). Prior to enrollment, all participants were comprehensively informed of the study content and signed a written informed consent form.

Research Equipment and Environment

All experiments were carried out in a specialized, environment - controlled high - fidelity medical simulation center. This center emulated a standard single - rescue room environment, furnished with an ambulance, monitors, defibrillators, and central oxygen supply facilities, to replicate real clinical scenarios to the greatest extent.

This research employed a sophisticated adult high-fidelity cardiopulmonary resuscitation (CPR) manikin (Resusci Anne QCPR, Laerdal Medical, Norway). The manikin is furnished with sensors that continuously and sequentially gauge and document all research parameters, such as the depth and frequency of chest compressions, chest wall recoil, and compression interruption time. The data are exported through the associated software (Laerdal SimPad PLUS System) for subsequent analysis.

This research utilized a commercially accessible mainstream mechanical chest compression device (MCC-E1, Sunlife Medical, China) founded on piston technology. Throughout the experiment, the device was uniformly configured to conform to the parameters recommended by the American Heart Association (AHA) guidelines, specifically a compression rate ranging from 100 to 120 compressions per minute and a compression depth of 5–6 cm. In the mechanical compression context, all team

members underwent standardized training regarding the rapid and accurate installation and activation of the device.

Procedure

Prior to the first experiment, all teams participated in a standardized 30 - minute training session, which encompassed the following aspects: (1) Familiarization with the research protocol and the experimental environment; (2) Review of the latest high - quality cardiopulmonary resuscitation (CPR) guidelines; (3) Emphasis on teamwork and the significance of rotating compressors every 2 minutes during manual compressions; (4) Practical operation of equipment assembly, positioning, and activation for mechanical compressions, guaranteeing that all team members could complete the deployment within 60 seconds.

Each team completed four simulated scenarios on four distinct dates in a randomly assigned sequence. The process of each scenario was as follows:

1. 1. Scenario Initiation (0 minutes): The team entered the simulated emergency room, where the mannequin presented a state of non - response, apnea, and pulselessness, with the monitor displaying the corresponding cardiac rhythm (either non - defibrillation or defibrillation - eligible).
2. 2. Initial Response and Initiation of Cardiopulmonary Resuscitation (CPR): The team leader (physician) allocated tasks. One nurse promptly initiated manual chest compressions (in manual compression scenarios) or prepared to deploy mechanical compression equipment (in mechanical compression scenarios), while another nurse managed the airway and ventilation.
3. 3. 15 - minute Simulated Resuscitation:

1) Manual Compression Group: Two nurses alternated roles every 2 minutes to mitigate fatigue. The physician was accountable for directing the resuscitation process, providing ventilation support, assessing the cardiac rhythm, administering simulated medications, and performing other advanced life support tasks. In defibrillation - eligible scenarios, compressions were halted at the 6th and 12th minutes for rhythm analysis and defibrillation.

2) Mechanical Compression Group: The team completed the deployment and activation of the equipment within 60 seconds. After activation, the equipment provided continuous, uninterrupted compressions. Nurses and physicians concentrated on executing other advanced life support procedures. In defibrillation - eligible scenarios, rhythm analysis and defibrillation were carried out against the backdrop of continuous mechanical compression.

1. 4. Scenario Conclusion (15 minutes): The simulated scenario concluded punctually.
2. 5. Data Collection: CPR quality data were automatically recorded throughout the process by the mannequin system.
3. 6. Within 1 minute after the scenario concluded, three team members independently completed the Borg Subjective Fatigue Perception Scale to acquire their fatigue scores(see Fig. 1).

Research Index Measurement

This research assessed seven crucial indicators, namely chest compression depth (unit: mm), chest compression rate (unit: times/min), percentage of correct compression depth (unit:%), chest compression rebound rate (unit:%), percentage of correct compression rate (unit:%), and chest compression score (unit:%). The Borg Subjective Fatigue Perception Scale (ranging from 6 to 20 points) was employed to gauge the fatigue scores of rescuers. For each group, the average fatigue scores of three team members were documented.

Statistical Analysis

In this study, all descriptive data are presented as means ± standard deviations. One-Way ANOVA was used to analyze differences in basic characteristics between groups. A mixed-design two-way ANOVA was used to explore the differences in cardiopulmonary resuscitation (CPR) quality between defibrillation and non-defibrillation scenarios at various phases in manual CPR and mechanical CPR.A One-Way Repeated Measurement ANOVA was performed to compare the quality of CPR across all teams in manual CPR and mechanical CPR cycle stages.All statistical analyses in this study were performed with GraphPad Prism statistical software (version8.0, GraphPad Software, San Diego, California, USA, www.graphpad.com). The statistical significance level was set as p less than 0.05.

Results

Comparison of General Characteristics of Study Subjects

A total of 60 participants were included in this study, comprising 20 physicians and 40 nurses. Among the physicians, the median age was 28.4 (27.26, 29.54) years, median height 176.00 (173.36, 178.64) cm, median weight 73.70 (70.78, 76.62) kg, mean clinical work experience 2.15 (1.36, 2.94) years, and mean duration since Advanced Cardiac Life Support (ACLS) certification 1.13 (0.73, 1.53) years. Among the nurses, the median age was 25.58 (24.08, 27.08) years, median height 162.63 (160.20, 165.06) cm, median weight 55.21 (51.75, 58.67) kg, mean clinical work experience 3.18 (1.75, 4.61) years, and mean duration since ACLS certification 1.28 (0.81, 1.75) years (see Table 1). No statistically significant differences were observed between the groups regarding age, height, weight, clinical work experience, or duration since ACLS certification (see Table 2).

Table 1
Baseline demographic and professional characteristics of participants Data are presented as mean ± standard deviation or number (percentage). ACLS = Advanced Cardiovascular Life Support.

Characteristic	Physicians(n = 20)	Nurses(n = 40)	Total(N = 60)
Age (years), mean ± SD	28.40 ± 1.14	25.58 ± 1.50	26.5 ± 1.8
Sex, n (%)			
Male	20 (100.00)	0 (0.00)	20 (33.33)
Female	0 (0.00)	40 (100.00)	40 (66.67)
Height (cm), mean ± SD	176.00 ± 2.64	162.63 ± 2.43	167.09 ± 6.71
Weight (kg), mean ± SD	73.70 ± 2.92	55.21 ± 3.46	61.37 ± 9.64
Education, n (%)			
Bachelor's degree	0 (0.00)	40 (100.00)	40 (66.67)
Master's degree	20 (100.00)	0 (0.00)	20 (33.33)
Years of clinical experience, mean ± SD	2.15 ± 0.79	3.18 ± 1.43	2.82 ± 1.35
Time since ACLS certification (years), mean ± SD	1.13 ± 0.40	1.28 ± 0.47	1.23 ± 0.45

Table 2
Team difference test

Characteristic	F value(df = 19,40)	p value
Age (years), mean ± SD	0.85	0.64
Height (cm), mean ± SD	0.63	0.86
Weight (kg), mean ± SD	0.71	0.79
Years of clinical experience, mean ± SD	0.92	0.56
Time since ACLS certification (years), mean ± SD	0.58	0.91

All p - values were > 0.05, suggesting that there were no statistically significant differences among the 20 teams regarding age, height, weight, clinical experience, and the duration since ACLS certification.

Comparison of Mechanical versus Manual Chest Compression Quality and Rescuer Fatigue in a Simulated In-Hospital Cardiac Arrest Scenario

Mechanical and Manual Chest Compression Quality and Rescuer Fatigue Values at Different Compression Phases in a Simulated In-Hospital Cardiac Arrest Scenario

The metrics for mechanical and manual chest compression quality and rescuer fatigue during different phases of a simulated in-hospital cardiac arrest scenario are presented in Table 3. Irrespective of the defibrillation scenario (shockable vs. non-shockable rhythm), the quality of manual chest compressions declined, the compression rate tended to increase, and the Rescuer Fatigue Score (RFP) progressively rose as compression duration increased. In contrast, the mechanical compression group exhibited minimal change in compression quality over the same time intervals.

Table 3
Compariseon of the quality of chest compression between manual CPR and mechanical CPR

	Non-defibrillation			Defibrillation		
	Manual CPR	**Mechanical CPR**	***p***	**Manual CPR**	**Mechanical CPR**	***p***
1-Phase						
CCD(mm)	59.15 ± 3.71	58.88 ± 1.06	0.988	57.32 ± 3.66	58.76 ± 1.03	0.295
CCR(cpm)	108.50 ± 3.94	110.00 ± 0.77	0.359	105.60 ± 3.85	109.82 ± 0.77	< 0.001
PCCD(%)	96.99 ± 3.19	99.22 ± 0.59	0.091	92.21 ± 4.88	98.65 ± 0.58	< 0.001
CCRR(%)	86.34 ± 5.09	95.75 ± 2.35	< 0.001	79.76 ± 3.72	94.76 ± 2.32	< 0.001
PCCR(%)	97.57 ± 2.95	99.59 ± 0.30	0.104	93.03 ± 4.43	98.98 ± 0.38	< 0.001
CCF(%)	93.23 ± 5.13	98.05 ± 0.66	0.003	82.69 ± 7.52	89.41 ± 1.07	< 0.001
CCQ(%)	19.53 ± 2.49	38.23 ± 2.29	< 0.001	15.52 ± 3.12	37.22 ± 2.29	< 0.001
RFP	11.31 ± 2.39	7.21 ± 1.06	< 0.001	13.33 ± 1.32	9.84 ± 2.01	< 0.001
2-Phase						
CCD(mm)	56.33 ± 3.53	59.10 ± 0.818	0.005	54.59 ± 3.49	58.39 ± 1.16	< 0.001
CCR(cpm)	110.70 ± 4.02	110.40 ± 0.62	0.983	107.76 ± 3.93	110.16 ± 0.83	0.043
PCCD(%)	94.69 ± 3.70	99.14 ± 0.49	< 0.001	89.53 ± 4.74	98.45 ± 0.66	< 0.001
CCRR(%)	83.83 ± 4.94	95.28 ± 2.34	< 0.001	77.44 ± 3.61	94.83 ± 2.42	< 0.001
PCCR(%)	95.41 ± 3.57	99.57 ± 0.25	< 0.001	90.34 ± 4.33	99.08 ± 0.24	< 0.001
CCF(%)	89.70 ± 5.03	98.29 ± 0.69	< 0.001	79.51 ± 7.23	89.79 ± 0.97	< 0.001
CCQ(%)	18.96 ± 2.42	38.43 ± 2.65	< 0.001	15.07 ± 3.03	37.75 ± 2.28	< 0.001
RFP	12.84 ± 2.40	7.29 ± 1.11	< 0.001	14.87 ± 1.34	10.35 ± 2.02	< 0.001

	Non-defibrillation			Defibrillation		
	Manual CPR	**Mechanical CPR**	***p***	**Manual CPR**	**Mechanical CPR**	***p***
1-Phase						
3-Phase						
CCD(mm)	53,51 ± 33.50	58.91 ± 1.07	< 0.001	51.86 ± 3.31	58.54 ± 1.15	< 0.001
CCR(cpm)	113.00 ± 4.10	110.00 ± 0.85	0.007	109.92 ± 4.01	109.30 ± 0.74	0.902
PCCD(%)	92.00 ± 3.87	99.13 ± 0.52	< 0.001	86.84 ± 4.60	98.50 ± 0.52	< 0.001
CCRR(%)	81.31 ± 4.79	94.80 ± 2.32	< 0.001	75.12 ± 3.51	94.97 ± 2.42	< 0.001
PCCR(%)	92.85 ± 3.95	99.58 ± 0.24	< 0.001	87.63 ± 4.20	98.85 ± 0.17	< 0.001
CCF(%)	86.11 ± 4.83	98.20 ± 0.70	< 0.001	76.33 ± 6.94	89.83 ± 1.10	< 0.001
CCQ(%)	18.39 ± 2.35	38.29 ± 2.64	< 0.001	14.62 ± 2.94	37.62 ± 2.28	< 0.001
RFP	14.39 ± 2.43	7.35 ± 1.12	< 0.001	16.35 ± 1.33	10.8 ± 2.03	< 0.001

Values are shown as the mean ± SD. 1-Phase:The first 5 minutes of CPR;2-Phase:The second 5-minute period of CPR;3-Phase:The last 5 minutes of CPR;The difference in CCR,PCCD,CCRR,PCCR,CCF,CCQ and RFP were statistically significant in 1-Phase;The difference in CCD,PCCD,CCRR,PCCR,CCF,CCQ and RFP were statistically significant in 2-Phase and 3-Phase.

Comparison of Mechanical and Manual Chest Compression Stability Across Different Phases in a Simulated In-Hospital Cardiac Arrest Scenario

Comparison of mechanical and manual chest compression stability across different phases of the simulated in-hospital cardiac arrest scenario revealed that the dispersion of Chest Compression Depth (CCD) and Chest Compression Rate (CCR) data was markedly higher in the manual compression group compared to the mechanical group. Consequently, compression stability was significantly diminished in the manual group relative to the mechanical group.(Figure2)

Comparison of Manual Chest Compression Quality and Fatigue Across Different Phases in a Simulated In-Hospital Cardiac Arrest Scenario

The results indicated that with increasing compression duration, manual chest compression parameters—including CCD, Percentage of Accurate Chest Compression Depth (PCCD), Correct Chest Compression Release Rate (CCRR), Percentage of Accurate Chest Compression Rate (PCCR), and overall Chest Compression Fraction (CCF)—exhibited a statistically significant declining trend across the phases. However, there was no significant decrease in Chest Compression Quality (CCQ) across the phase.Conversely, CCR and Rescuer Fatigue Score (RFP) demonstrated an upward trend as compression duration increased.(Fig. 3)

Comparison of Mechanical and Manual Chest Compression Quality and Fatigue Across Different Phases in a Simulated In-Hospital Cardiac Arrest Scenario

The results demonstrated no significant differences across the phases for mechanical compressions in both non-defibrillation and defibrillation scenarios. During the initial phase (Phase 1), with the exception of CCD, significant differences were observed between manual and mechanical compressions for all metrics including CCR, PCCD, CCRR, CCF, CCQ, and RFP. During the subsequent phases (Phases 2 and 3), all measured parameters exhibited significant differences between manual and mechanical compressions.(Fig. 4)

Discussion

Cardiac arrest remains one of the leading causes of mortality worldwide, with an estimated incidence of 52.1 cases per 100,000 person-years. Survival rates vary considerably, ranging from approximately 5% to 50% across out-of-hospital and in-hospital settings [16]. Over half of cardiac arrest survivors experience varying degrees of neurological impairment [17]. Early, high-quality cardiopulmonary resuscitation (CPR) has been established as a critical determinant of outcomes during resuscitation. The American Heart Association recommends a chest compression rate of 100–120 compressions per minute and a compression depth of at least 5 cm during CPR. In pursuit of enhancing resuscitation quality, two types of mechanical CPR devices received approval for marketing in the United States in the 21st century. Their primary mechanism involves piston-driven or load-distributing band compression to simulate manual compressions. However, multiple studies, including nine randomized controlled trials and six non-randomized controlled trials, have found no significant difference in resuscitation outcomes between mechanical and manual CPR [13, 18–21].Previous investigations have often aggregated out-of-hospital and in-hospital cardiac arrest data to draw conclusions. Notably, out-of-hospital and in-hospital settings differ substantially; in-hospital environments typically offer more comprehensive resources and staffing. Therefore, this study specifically investigated the characteristics and disparities between mechanical and manual chest compressions within the context of in-hospital cardiac arrest scenarios.

Differences in Chest Compression Quality Stability Between Mechanical and Manual Compressions in a Simulated In-Hospital Cardiac Arrest Scenario

By conducting 15-minute CPR sessions under both non-defibrillation and defibrillation scenarios and segmenting the 15-minute period into three distinct phases, we observed that irrespective of the scenario, manual compressions exhibited lower stability in quality metrics such as compression depth and rate. This instability may contribute to incomplete chest recoil and reduced coronary perfusion time. Mechanical compressions demonstrated superior stability compared to manual compressions, an aspect not explicitly evaluated in previous studies. In this investigation, the superiority of mechanical compression stability became increasingly pronounced with prolonged compression duration. Once optimal parameters are set, the compression mechanism of the mechanical CPR device operates with greater consistency, conferring a distinct advantage over manual compressions.

Comparison of Mechanical and Manual Chest Compression Quality and Fatigue Across Different Phases in a Simulated In-Hospital Cardiac Arrest Scenario

When analyzing the three phases, all chest compression-related metrics for mechanical compressions remained consistent across phases, whereas the Rescuer Fatigue Score (RFP) increased with prolonged duration. This rise in fatigue is likely attributable to the ongoing execution of other resuscitative interventions, despite the provider being relieved from performing compressions. In the manual compression group, significant differences were observed in compression quality, CCF values, and fatigue scores as the duration increased, indicating a decline in compression quality concomitant with rising fatigue levels. This finding aligns with the study by Hallstrom et al., which compared standard manual chest compressions provided by healthcare personnel with use of the LDB device in multiple cardiac arrest patients [22, 23]. This deterioration is attributed to rescuer physical fatigue during prolonged CPR scenarios. Notably, we observed a significant increase in manual compression rate over time, accompanied by a decrease in the percentage of accurate compression rate. Post-study debriefing with participants suggests that this phenomenon may be related to heightened resuscitative stress and neurohumoral excitation; however, more definitive and objective metrics are required for further evaluation.

Comparison of Mechanical and Manual Chest Compression Quality and Fatigue Across Different Phases in a Simulated In-Hospital Cardiac Arrest Scenario

Comparative analysis of mechanical versus manual compressions across the different phases revealed that during Phase 1, while manual compression depth and rate showed no significant difference from mechanical compressions in the non-defibrillation scenario (though differences were noted in the defibrillation scenario), overall compression quality, chest recoil efficacy, and CCF were significantly superior with mechanical compressions. This indicates the overall advantage of mechanical compressions. In Phases 2 and 3, under both non-defibrillation and defibrillation conditions, mechanical compressions demonstrated significantly better compression quality, higher CCF, and lower rescuer fatigue scores (RFP) compared to manual compressions. Although rescuer fatigue increased slightly in the mechanical compression group over time, it remained markedly lower than that observed in the corresponding phases of the manual compression group. These findings underscore the superiority of

mechanical compressions across various CPR quality indicators in the in-hospital cardiac arrest setting. Prior research in out-of-hospital cardiac arrest has suggested that mechanical CPR does not confer a survival benefit compared to manual CPR [13, 24].

However, three studies have indicated an association between mechanical CPR device use and improved short-term resuscitation outcomes, such as Return of Spontaneous Circulation (ROSC) or survival to hospital admission [25–27].A meta-analysis of out-of-hospital data suggests that prehospital mechanical CPR device use may be beneficial for achieving ROSC and survival to hospital admission in adult patients [28, 29]. This observation is consistent with the findings of the present study, which demonstrate that in-hospital use of mechanical CPR devices enhances compression quality and CCF, thereby potentially improving resuscitation success rates.

Regarding rescuer fatigue, fatigue scores were significantly higher in the manual compression group compared to the mechanical compression group. Elevated fatigue levels not only directly compromise compression quality but may also indirectly impair decision-making capacity, communication efficiency, and the accuracy of performing other advanced life support interventions. This effect was particularly pronounced in defibrillation scenarios requiring additional procedural tasks and heightened cognitive focus, where fatigue intensified significantly in the manual compression group. This indicates that within the in-hospital cardiac arrest setting, mechanical CPR not only serves as a substitute for manual compressions but also liberates the rescuer's hands, thereby enhancing overall resuscitation efficiency and quality.

Limitations

Further randomized clinical trials are warranted to elucidate the differential impact of mechanical versus manual chest compressions on cardiac resuscitation outcomes.

The provider-to-patient ratio and team composition in the simulated cardiac arrest scenario may differ from real-world resuscitation events.

This study did not incorporate additional quality indicators of CPR efficacy, such as cerebral blood flow perfusion, post-resuscitation echocardiographic findings, or end-tidal carbon dioxide ($ETCO_2$) monitoring; therefore, the results may not fully represent overall CPR treatment effectiveness.

Conclusion

1. In a simulated in-hospital cardiac arrest scenario, mechanical chest compression stability is significantly superior to manual chest compression stability across all phases.
2. In a simulated in-hospital cardiac arrest scenario, mechanical chest compression quality and Chest Compression Fraction (CCF) are significantly superior to manual compressions, with the difference being more pronounced in complex scenarios involving defibrillation.
3. Mechanical CPR device utilization significantly reduces rescuer fatigue compared to manual CPR.

Declarations

Ethics approval and consent to participate

According to the ethical principles of the Measures for Ethical Review of Research Involving Human Subjects in Life Sciences and Medical Research (2023) jointly issued by the National Health Commission, the Ministry of Education, the Ministry of Science and Technology, and the National Administration of Traditional Chinese Medicine; the Good Clinical Practice for Drug Trials (2020) issued by the National Medical Products Administration and the National Health Commission; the Measures for Ethical Review of Biomedical Research Involving Human Subjects (2016) issued by the former National Health and Family Planning Commission; the Declaration of Helsinki (2013) of the World Medical Association (WMA); and the International Ethical Guidelines for Health-related Research Involving Humans (2016) of the Council for International Organizations of Medical Sciences (CIOMS).The ethics Committee of Maternal and Child Health Hospital of Hubei Province has reviewed and approved the conduct of this research in accordance with the approved research protocol, informed consent form, and other relevant documents(2026-028-01).The written informed consent for participation in this study was provided by the participants.

Consent for publication

Not applicable

Clinical trial number:

Not applicable

Availability of data and materials

The datasets used during the current study are available from the corresponding author on reasonable request.

Competing interests

The author(s) declared that this work was conducted in the absence of any commercial or

financial relationships that could be construed as a potential conflict of interest.

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of Maternal and Child Health Hospital of Hubei Province

Authors' contributions

J.Y.:Conceptualization, Data curation, Formal analysis,Methodology, Project administration,Validation, Writing – original draft.Q.W.:Conceptualization, Data curation, Formal analysis,Methodology, Project administration,Validation, Writing – original draft.L.J.: Formal analysis, Datacuration, Investigation, Project administration.R.W.: Conceptualization,Formal analysis, Validation, Writing – review & editing.J.W.: Formal analysis, Validation, Writing – review & editing.J.Z.: Data curation, Investigation, Project administration.Z.X.: Data curation, Investigation, Project administration.H.H.: Data curation, Investigation, Project administration.Z.Q.: Data curation, Investigation, Project administration.X.Y.: Data curation, Project administration,M.Y.: Data curation, Project administration,R.D.: Data curation, Project administration,H.Z.: Conceptualization, Formal analysis,Funding acquisition,Methodology, Resources, Supervision,Validation, Visualization,Writing – review & editing.

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References

1. DAMPS M, BUCZYŃSKI M. WIKTOR Ł. Extracorporeal Cardiopulmonary Resuscitation-A Chance for Survival after Sudden Cardiac Arrest [J]. Child (Basel), 2023, 10(2).
2. LAZZARIN T, TONON C R, MARTINS D et al. Post-Cardiac Arrest: Mechanisms, Management, and Future Perspectives [J]. J Clin Med, 2022, 12(1).
3. VARGHESE J, THOMAS A, PRASAD B S, et al. Improving Cardiopulmonary Resuscitation Quality and Resuscitation Training by Using Real-Time Audiovisual-Assisted Devices [J]. Cureus. 2024;16(9):e68757.
4. GANNON W D, STOKES J W, PUGH M E, et al. Simulation Versus Interactive Mobile Learning for Teaching Extracorporeal Membrane Oxygenation to Clinicians: A Randomized Trial [J]. Crit Care Med. 2022;50(5):e415–25.
5. OLASVEENGEN T M, SEMERARO F, RISTAGNO G, et al. European Resuscitation Council Guidelines 2021: Basic Life Support [J]. Resuscitation. 2021;161:98–114.
6. SEEWALD S, DOPFER S, WNENT J, et al. Differences between manual CPR and corpuls cpr in regard to quality and outcome: study protocol of the comparing observational multi-center prospective registry study on resuscitation (COMPRESS) [J]. Scand J Trauma Resusc Emerg Med. 2021;29(1):39.
7. PECHAKSORN N. VATTANAVANIT V. CPR Compression Rotation Every One Minute Versus Two Minutes: A Randomized Cross-Over Manikin Study [J]. Emerg Med Int, 2020, 2020: 5479209.
8. NEUMANN T, GRUENEWALD M, LAUENSTEIN C, et al. Hands-on defibrillation has the potential to improve the quality of cardiopulmonary resuscitation and is safe for rescuers-a preclinical study [J]. J Am Heart Assoc. 2012;1(5):e001313.
9. KERN K B, HILWIG R W, BERG RA, et al. Importance of continuous chest compressions during cardiopulmonary resuscitation: improved outcome during a simulated single lay-rescuer scenario

[J]. Circulation. 2002;105(5):645–9.
10. BABINI G, RUGGERI L. Optimizing defibrillation during cardiac arrest [J]. Curr Opin Crit Care. 2021;27(3):246–54.
11. ZHAO Y, CHEN D, WANG Q. Comparison of mechanical versus manual cardiopulmonary resuscitation in cardiac arrest [J]. Crit Care. 2024;28(1):319.
12. CROWLEY C, SALCICCIOLI J, POCOCK H, et al. Manual mastery vs. mechanized magic: current opinions on manual vs. mechanical chest compressions [J]. Curr Opin Crit Care. 2024;30(6):597–602.
13. ZHU N, CHEN Q, JIANG Z, et al. A meta-analysis of the resuscitative effects of mechanical and manual chest compression in out-of-hospital cardiac arrest patients [J]. Crit Care. 2019;23(1):100.
14. LARIK M O AHMEDA, SHIRAZ M I, et al. Comparison of manual chest compression versus mechanical chest compression for out-of-hospital cardiac arrest: A systematic review and meta-analysis [J]. Med (Baltim). 2024;103(8):e37294.
15. SUGERMAN N T, EDELSON D P, LEARY M, et al. Rescuer fatigue during actual in-hospital cardiopulmonary resuscitation with audiovisual feedback: a prospective multicenter study [J]. Resuscitation. 2009;80(9):981–4.
16. BERG RA, HEMPHILL R, ABELLA B S, et al. Part 5: adult basic life support: 2010 American Heart Association Guidelines for Cardiopulmonary Resuscitation and Emergency Cardiovascular Care [J]. Circulation. 2010;122(18 Suppl 3):S685–705.
17. HERLITZ J, ANDERSSON E, BåNG A, et al. Experiences from treatment of out-of-hospital cardiac arrest during 17 years in Göteborg [J]. Eur Heart J. 2000;21(15):1251–8.
18. WANG P. Cochrane corner: Are mechanical compressions better than manual compressions in cardiac arrest? [J]. Heart. 2020;106(8):559–61.
19. LIU M, SHUAI Z, AI J, et al. Mechanical chest compression with LUCAS device does not improve clinical outcome in out-of-hospital cardiac arrest patients: A systematic review and meta-analysis [J]. Med (Baltim). 2019;98(44):e17550.
20. LI H, WANG D, YU Y, et al. Mechanical versus manual chest compressions for cardiac arrest: a systematic review and meta-analysis [J]. Scand J Trauma Resusc Emerg Med. 2016;24:10.
21. BONNES JL, BROUWER M A, NAVARESE E P et al. Manual Cardiopulmonary Resuscitation Versus CPR Including a Mechanical Chest Compression Device in Out-of-Hospital Cardiac Arrest: A Comprehensive Meta-analysis From Randomized and Observational Studies [J]. Ann Emerg Med, 2016, 67(3): 349 – 60.e3.
22. HALPERIN H R, TSITLIK J E, GELFAND M, et al. A preliminary study of cardiopulmonary resuscitation by circumferential compression of the chest with use of a pneumatic vest [J]. N Engl J Med. 1993;329(11):762–8.
23. HALLSTROM A, REA T D, SAYRE M R, et al. Manual chest compression vs use of an automated chest compression device during resuscitation following out-of-hospital cardiac arrest: a randomized trial [J]. JAMA. 2006;295(22):2620–8.

24. LYON RM, CRAWFORD A, CROOKSTON C, et al. The combined use of mechanical CPR and a carry sheet to maintain quality resuscitation in out-of-hospital cardiac arrest patients during extrication and transport [J]. Resuscitation. 2015;93:102–6.
25. SHERATON M, COLUMBUS J, SURANI S, et al. Effectiveness of Mechanical Chest Compression Devices over Manual Cardiopulmonary Resuscitation: A Systematic Review with Meta-analysis and Trial Sequential Analysis [J]. West J Emerg Med. 2021;22(4):810–9.
26. SEEWALD S, OBERMAIER M, LEFERING R, et al. Application of mechanical cardiopulmonary resuscitation devices and their value in out-of-hospital cardiac arrest: A retrospective analysis of the German Resuscitation Registry [J]. PLoS ONE. 2019;14(1):e0208113.
27. CHEN Y R, LIAO C J, HUANG H C et al. The Effect of Implementing Mechanical Cardiopulmonary Resuscitation Devices on Out-of-Hospital Cardiac Arrest Patients in an Urban City of Taiwan [J]. Int J Environ Res Public Health, 2021, 18(7).
28. SAVASTANO S, BALDI E, PALO A, et al. Load distributing band device for mechanical chest compressions: An Utstein-categories based analysis of survival to hospital discharge [J]. Int J Cardiol. 2019;287:81–5.
29. CHIANG C, Y, LIM K C, LAI P C et al. Comparison between Prehospital Mechanical Cardiopulmonary Resuscitation (CPR) Devices and Manual CPR for Out-of-Hospital Cardiac Arrest: A Systematic Review, Meta-Analysis, and Trial Sequential Analysis [J]. J Clin Med, 2022, 11(5).

Figures

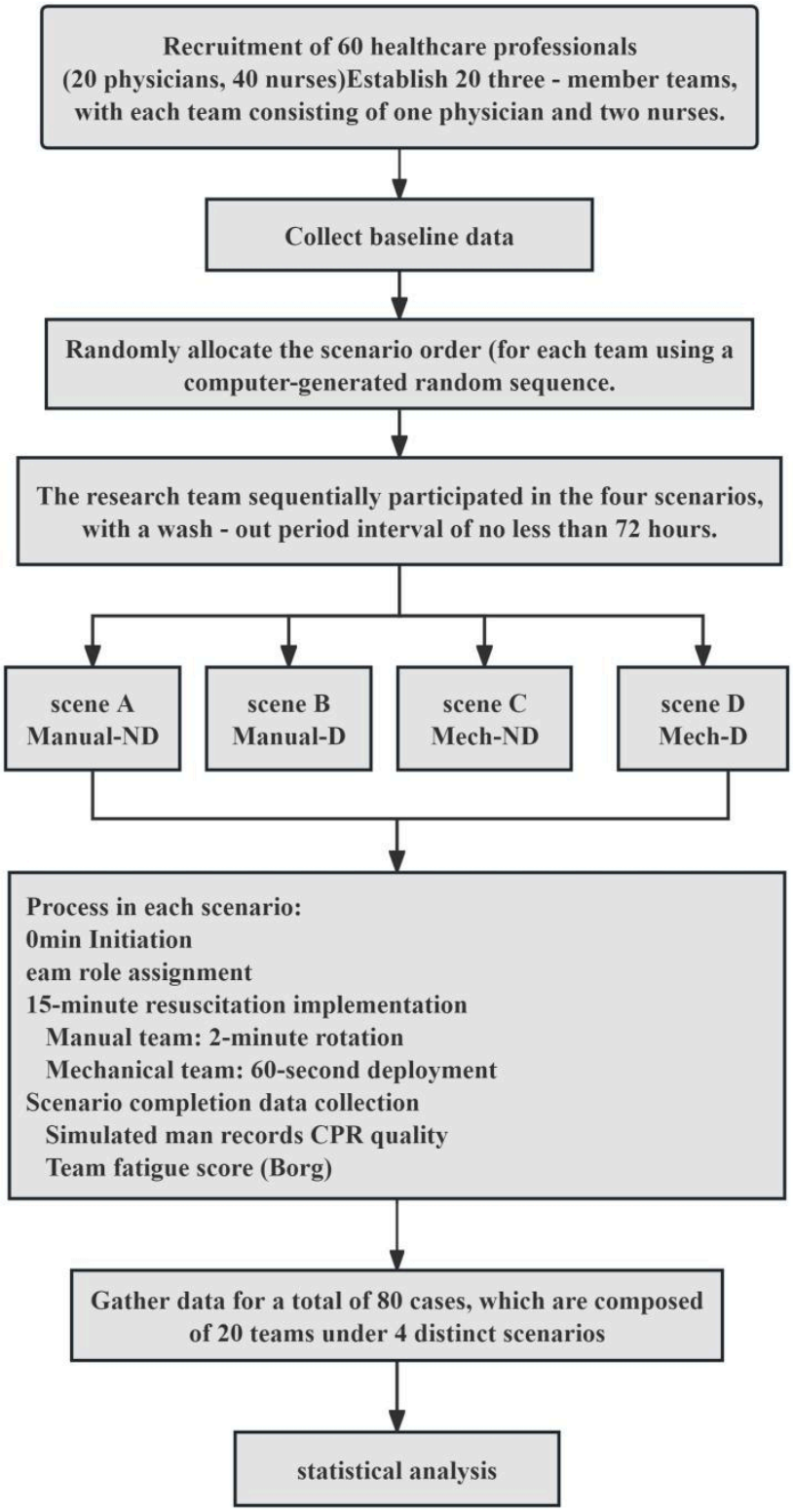


Figure 1

Flowchart of the experimental procedure.

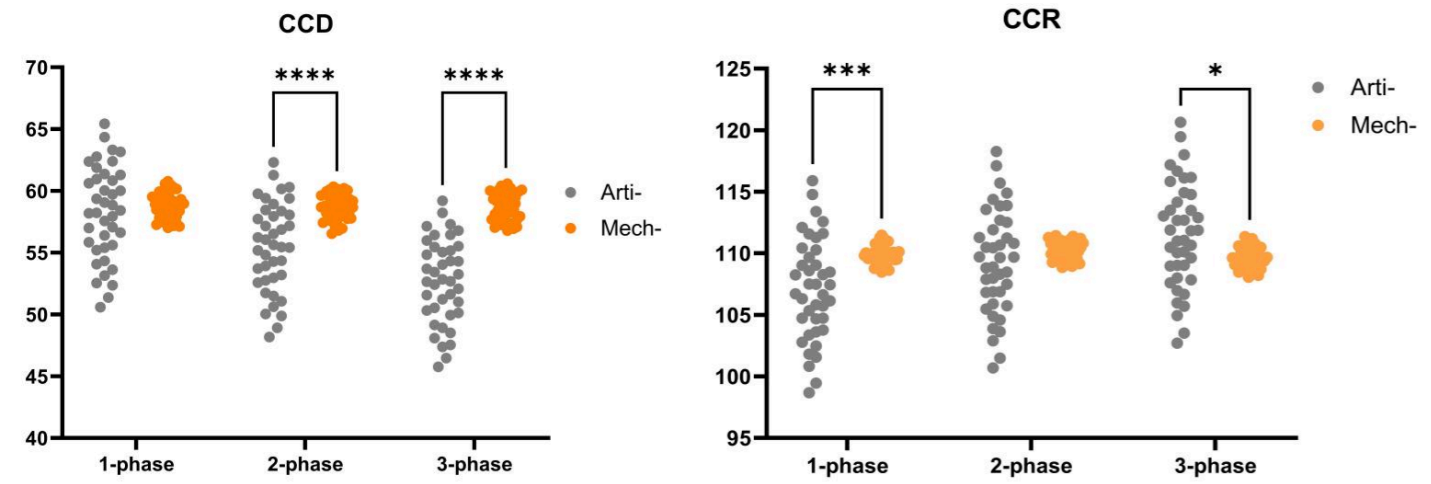


Figure 2

In both CCD and CCR, the data from the mechanical group (Mech-) is relatively concentrated, while that from the manual group(Arti-) is more dispersed

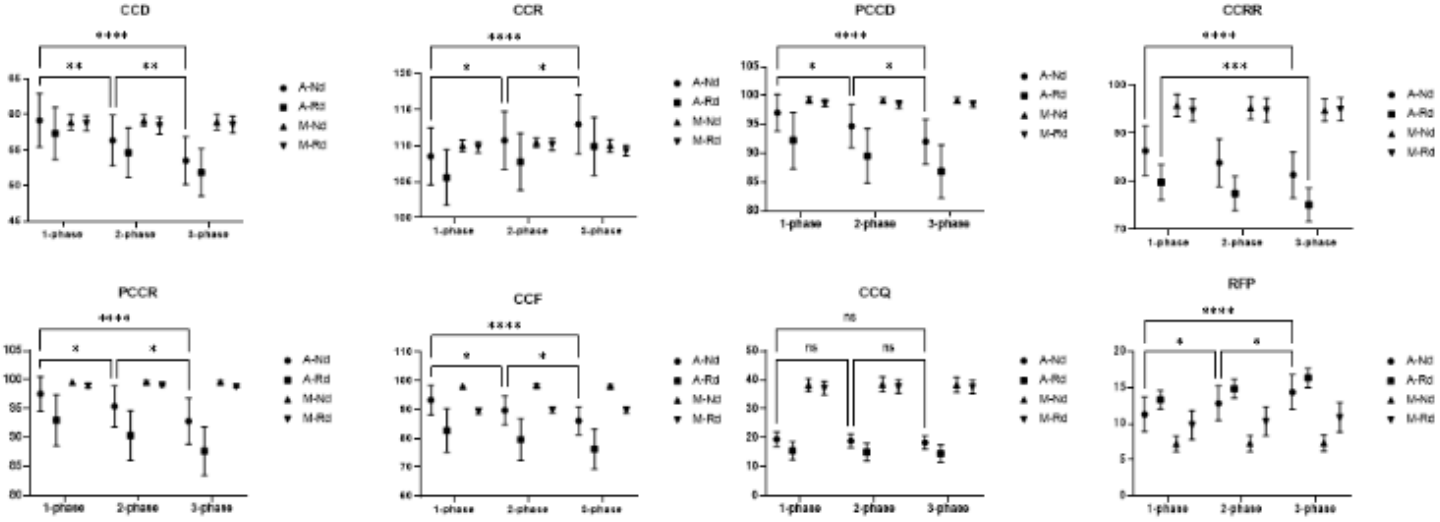


Figure 3

A-Nd:Manual CPR in Non-defibrillation;A-Rd:Manual CPR in defibrillation;M-Nd:Mechanical CPR in Non-defibrillation;M-Rd:Mechanical CPR in defibrillation;The difference in CCD,CCR,PCCD,CCRR,PCCR,CCF and RFP were statistically significant in 1-Phase,2-Phase and 3-Phase.

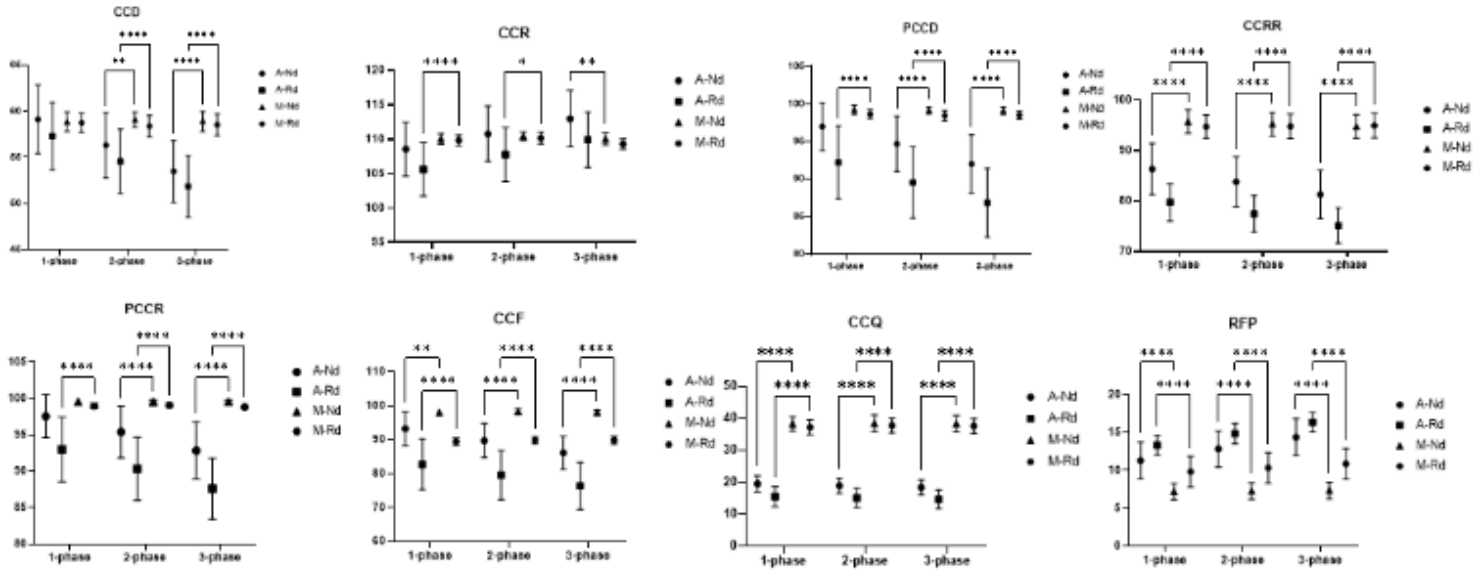


Figure 4

A-Nd:Manual CPR in Non-defibrillation;A-Rd:Manual CPR in defibrillation;M-Nd:Mechanical CPR in Non-defibrillation;M-Rd:Mechanical CPR in defibrillation;